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SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No 0704-0188

AD-A264 872

DTIC ELECTE MAY 26 1993 S A D

1b. RESTRICTIVE MARKINGS	
3. DISTRIBUTION/AVAILABILITY OF REPORT	Approved for public release; distribution unlimited
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	
5. MONITORING ORGANIZATION REPORT NUMBER(S)	AFOSR-TR- 4
6a. NAME OF PERFORMING ORGANIZATION	Texas Tech University, Dept. of Electrical Engr.
6b. OFFICE SYMBOL (If applicable)	
7a. NAME OF MONITORING ORGANIZATION	Air Force Office of Scientific Research
6c. ADDRESS (City, State, and ZIP Code)	P.O. Box 4439, Lubbock, Texas 79409-3102
7b. ADDRESS (City, State, and ZIP Code)	Building 410, Bolling AFB, DC 20332
8a. NAME OF FUNDING/SPONSORING ORGANIZATION	AFOSR
8b. OFFICE SYMBOL (If applicable)	AFOSR/NE
9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER	AFOSR Grant 91-0192
8c. ADDRESS (City, State, and ZIP Code)	Bolling AFB, DC 20332

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO	WORK UNIT ACCESSION NO
61102F	2305	DS	

11. TITLE (Include Security Classification)

Accuracy Enhancement in Optical Computing

12. PERSONAL AUTHOR(S)

John F. Walkup and Thomas F. Krile

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
~~Interim~~ Annual	FROM 3/1/92 TO 2/28/93	1993, March 25	36

16. SUPPLEMENTARY NOTATION

Annual Technical Report

17. COSATI CODES

FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)

Optical Computing, Accuracy Enhancement, Error Correction Coding, Statistical Optics, Optical Matrix-Vector Multipliers

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Investigations of techniques for describing and enhancing the accuracy of optical linear algebra processors have been conducted. Significant accomplishments include: (1) Development and simulation of a system model incorporating device dynamic range for better quantitative assessment of error-correcting code performance; (2) extension of earlier statistical models to include crosstalk, background, avalanche gain, flicker and generation-recombination noise effects; (3) construction of the Optical Analysis Simulation Interactive System (OASIS) software for the acquisition, analysis and manipulation of experimental data and (4) identification of major noise sources of experimental concern using OASIS.

93-11617

93 5 25 068

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT	☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS
21. ABSTRACT SECURITY CLASSIFICATION	UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL	Dr. Alan E. Craig
22b. TELEPHONE (Include Area Code)	202-767-4931
22c. OFFICE SYMBOL	AFOSR/NE

ACCURACY ENHANCEMENT IN OPTICAL COMPUTING

Annual Technical Report

on

AFOSR Grant 91-0192

March 1, 1992 - February 28, 1993

by

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March 1993

ABSTRACT

Investigations of techniques for describing and enhancing the accuracy of optical linear algebra processors have been conducted. Significant accomplishments include: (1) development and simulation of a system model incorporating device dynamic range for better quantitative assessment of error-correction code performance; (2) extension of earlier statistical models to include crosstalk, background, avalanche gain, flicker and generation-recombination noise effects; (3) construction of the Optical Analysis Simulation Interactive System (OASIS) software for the acquisition, analysis and manipulation of experimental data and (4) identification of major noise sources of experimental concern using OASIS.

RESEARCH OBJECTIVES

During the second grant funding period (March 1, 1992-February 28, 1993), the major research objectives have been to continue both analytical and experimental investigations on techniques for enhancing the accuracy of optical linear algebra processors. This work has been divided into three separate but related areas: (1) an investigation of error correction/detection techniques for use in quantized analog optical linear algebra processor applications (2) complete statistical modeling of a generic optical vector-matrix multiplier taking into account noise effects in sources, spatial light modulators (SLMs) and detectors to predict overall noise performance and (3) experimental characterization of sources, SLMs, and detectors via a low-noise measurement facility and associated data acquisition and analysis software. Details of these investigations are presented in the following sections and in the publications referenced.

SUMMARY OF RESULTS

Since most of the results obtained under the grant are promptly submitted for publication, and are also presented at national and international scientific meetings, we will summarize the major results obtained in this section, with references to the appropriate journal articles and conference proceedings.

1. Encoding/Decoding for Error Correction in Optical Computing

This phase of the program involves finding and/or developing error-correction codes that can be applied to optical linear algebra processors (OLAPs) to enhance their accuracy. Error-correction codes have been successfully applied to increase the reliability of data transmission systems. The codes introduce a controlled amount of redundant information into the transmitted data. At the receiver, the redundant information allows errors in the received data to be detected and/or corrected, thus improving the reliability of the transmission system. In a similar manner, this idea can be applied to OLAPs[1,2,3,4]. Consider an optical matrix-vector multiplier (OMVM). Redundant information can be introduced into the matrix by increasing the row dimension of the matrix. The additional rows in the matrix are formed as linear combinations of the rows of the original matrix. These new rows provide the redundant information. The augmented matrix is now post

multiplied by the input vector to form the product vector. The product vector contains redundant information that can be used to correct errors in the elements of the product vector. Errors can occur during the matrix-vector multiplication due to noise in the system or due to component failures.

A block diagram of an OMVM employing an error-correction code is shown in Figure 1. In general, an OMVM is designed to implement the matrix-vector multiplication

$$\mathbf{y} = \mathbf{A}\mathbf{x} \tag{1}$$

where $\mathbf{A}$ is an M X N matrix and $\mathbf{x}$ is an N X 1 vector. Redundancy is introduced into the matrix by premultiplying the matrix by the generator matrix $\mathbf{G}$ for an error code, or $\mathbf{A}_C = \mathbf{GA}$. The encoder performs this operation. The generator matrix $\mathbf{G}$ is an M_C X M matrix

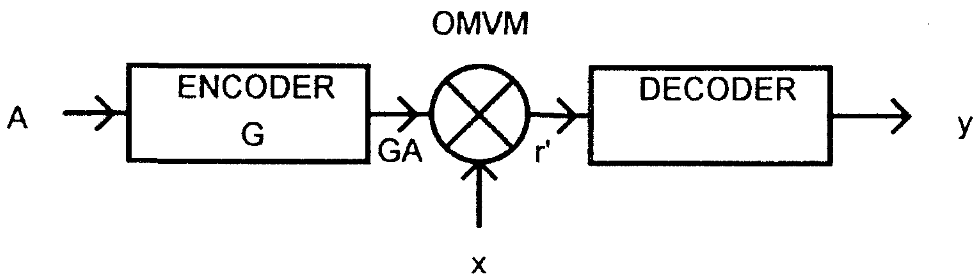

Figure 1. Block diagram of an optical matrix-vector multiplier employing an error-correction code.

with $M_C > M$. Next the product $\mathbf{A}_C\mathbf{x} = \mathbf{GAx} = \mathbf{r}'$ is computed in the OMVM. The product $\mathbf{r}'$ may contain errors as discussed earlier. Note that the multiplication $\mathbf{GAx} = \mathbf{Gy}$ is equivalent to encoding the vector $\mathbf{y}$ as is done for data transmission. Therefore, the same decoding algorithm is applied to $\mathbf{r}'$ as for the case of data transmission. The decoder performs the error detection and correction operations to produce $\mathbf{y}$. If $\mathbf{r}'$ contains more errors than the code can correct, then the output will not be $\mathbf{y}$ in general. Having to compute a higher-dimension matrix-vector product is traded for the ability to correct errors.

Our work to date has involved comparing the performance of OMVMs employing error-correction codes to OMVMs not employing the codes through the use of computer simulations. The results of this research have been published in [3] and [4]. To allow for a more quantitative assessment of the ability of the codes to enhance the accuracy of an OMVM, a new model of an OMVM that incorporates the dynamic ranges of the devices has been developed. Using this new model, various computer simulations have been performed that give a quantitative value for the accuracy increase. Figure 2 shows one simulation result. The graph was obtained by using the single-error-correcting code presented in [1]. For a signal-to-noise ratio (SNR_y) of approximately 8, i.e. approximately 18 db., in the output of the OMVM, an accuracy increase of approximately .3 bits can be obtained. For this

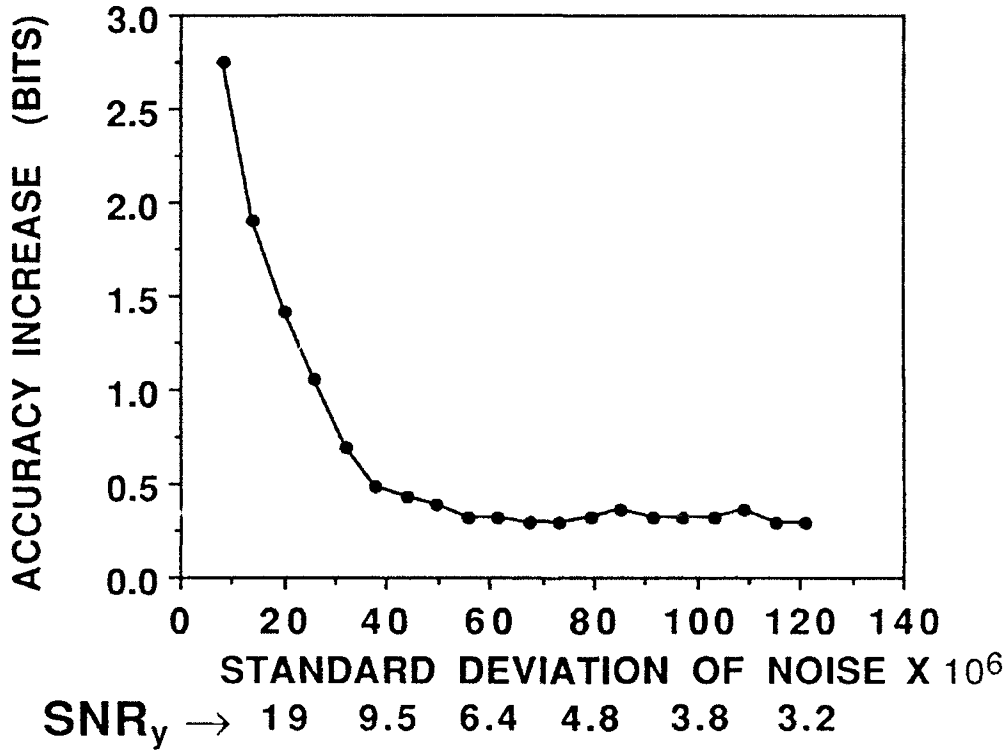

Figure 2. Accuracy increase versus signal-to-noise ratio in output

simulation, a strict error measure was employed. An error is said to have occurred if any component of the product vector is incorrect. By using a less stringent error measure, such as mean square error, the accuracy increase should be greater. Codes capable of correcting more errors should provide an even greater improvement. Currently, research continues in this area.

Various techniques have been introduced over the past decade to achieve high accuracy computation with analog optical matrix-vector multipliers (OMVMs). The two most discussed are digital multiplication by analog convolution (DMAC) and the residue number system. Recently, a new technique, digital partitioning, has been proposed [5]. The basic idea behind digital partitioning is to divide a large dynamic range matrix-vector product into a series of smaller dynamic range subproducts. A weighted sum of these subproducts will give the large dynamic range final matrix-vector product. One potential drawback of digital partitioning is the effect of small errors in the individual subproducts. The errors can occur due to noise in the analog system and also due to component failures. A small error that occurs in one of the subproducts that is then weighted by a large factor, will result in a larger error in the final matrix-vector product. This effect can significantly degrade the performance of the digital partitioning technique. An algorithmic technique that can

reduce this error amplification effect is the application of error-correction codes.

Error-correction codes reduce the error amplification effect of the digital partitioning technique by correcting the small errors in the subproducts and thus not allowing them to be weighted by a large weighting factor and resulting in a larger error in the final result. The codes accomplish this error-correction by the introduction of redundant information into each matrix-vector subproduct as discussed above. The resulting redundant information in each vector subproduct allows the correction of some errors. The number and magnitude of errors that can be corrected is dependent upon the amount of redundant information introduced. We are currently investigating the application of error-correction codes to combating the error amplification effect of the digital partitioning algorithm. Various computer simulations are being performed that show the reduction in the error magnitude. Figure 3 shows the result of one of our computer simulations. This graph is a plot of the root-mean-square (rms) error divided by

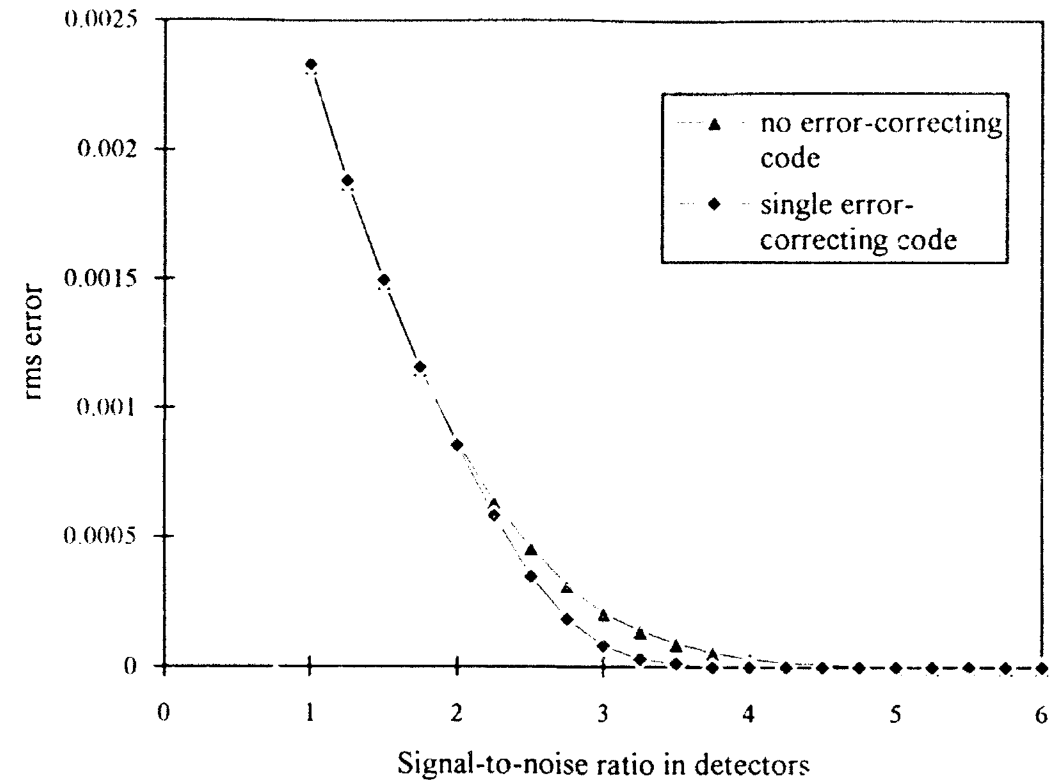

Figure 3. Graph of rms error versus signal to noise ratio in detector for the cases of no error-correcting code and a single error-correcting multilevel Hamming code.

the length of the output vector versus the signal to noise ratio in the detector. One curve shows the performance when no error-correction code is being used while the other curve shows the performance with a single-error-correcting multilevel Hamming code. There is clearly a region between very low and very high noise levels in which the error-correction code can improve performance.

In addition to the research mentioned above, we are investigating the effects of scaling the codes to higher dimension matrix-vector products. Since the benefits of the codes are gained at the expense of more computations, an analysis of the additional computations required is being made. Codes more suitable to OMVMs are being developed also. Some codes currently used have the drawbacks of requiring more levels to represent the redundant information than the actual data [1] or the codes require that a residue matrix-vector multiplication be performed. Optical implementations of the encoders and decoders are also being investigated.

2. Statistical Analysis and Modeling of Optical Processors

The two main objectives of this phase of our research have been (1) to broaden the range of validity of our earlier statistical analysis and modeling, and (2) to apply the general analysis to specific cases of interest in an effort to gain a more pragmatic view of the system performance.

Our earlier work involved a general statistical analysis of the Stanford optical matrix-vector multiplier [6] [see Figure 4] under certain simplifying assumptions, establishing the probability density and mutual coherence functions of the detector field intensity and the detector output current in terms of the statistical characteristics of the system components [7]. Specifically, we considered the effects of diffraction leading to an interchannel crosstalk, carefully analyzed the effects of the photodetection process [see Figure 5] on the signal statistics, and incorporated various postdetection noise processes [see Figure 6] into our final results [8, 9]. The expressions produced by this effort proved to be relatively complicated and generally intractable even under the most idealized conditions [5, 6].

One of our goals over the past year has been to extend our analysis to account for more realistic situations. In

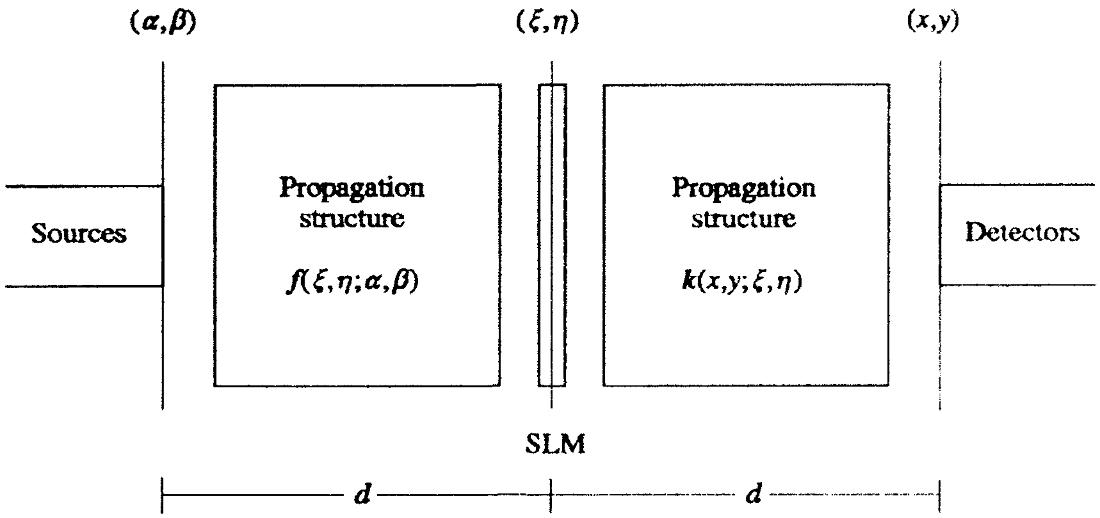

Figure 4 Block diagram of the Stanford optical matrix-vector multiplier

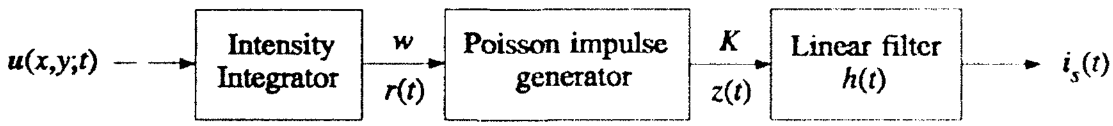

Figure 5 Block diagram of the photodetection process

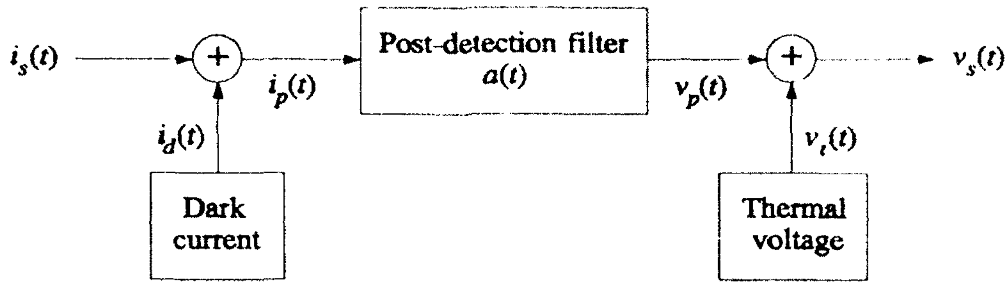

Figure 6 Block diagram of the post-detection processing

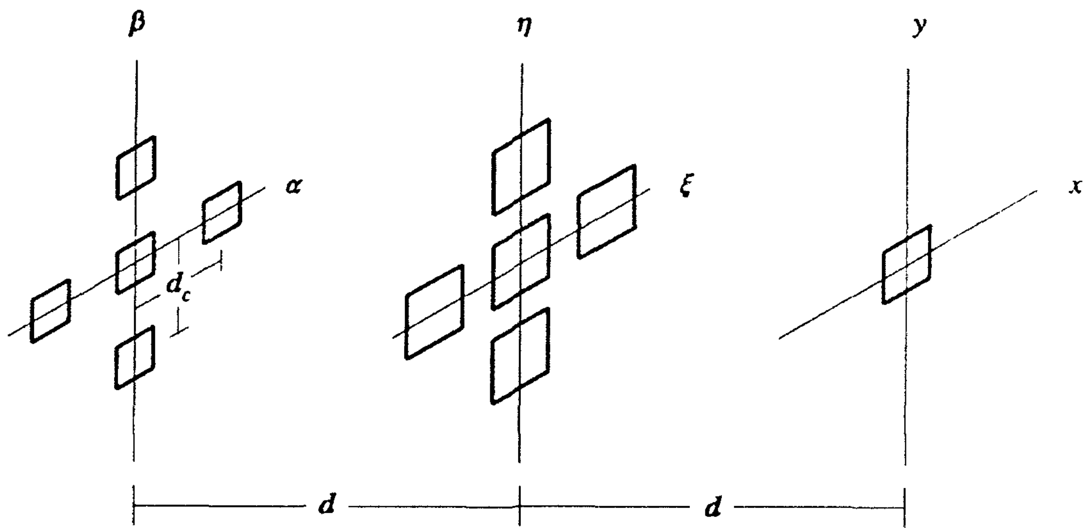

Figure 7 Channel geometry for crosstalk analysis

particular, we have attempted a more complete optical analysis of the system by bringing in the crosstalk and background effects, which were previously mildly studied or altogether neglected [12, 13, 14]. We used the more realistic *Rayleigh-Sommerfeld* diffraction formula, rather than the *Fresnel* and *Fraunhofer* approximations, to be able to come up with a faithful statistical representation for the crosstalk [see Figure 7]. Background light fields, on the other hand, were modeled as zero-mean and uncorrelated Gaussian processes, as is commonly done in astronomical optics. In the photodetection and postdetection stages, we extended our analysis to include the possibility of (avalanche) gain noise, and also brought in other noise sources, such as the $1/f$ noise and the generation-recombination noise, to complete our work [15].

Another goal in our investigation was to put our results in a more pragmatic perspective by exploring the practical implications of these theoretical results. Specifically, we considered classical sources such as lasers and LEDs for which the device statistics have been well established. Since statistical models for SLMs are currently unavailable, we considered theoretical models such as Gaussian and Bernoulli for the intensity transmittances of these devices. Deterministic modulation effects in the sources and SLMs can easily be accounted for if desired, and

were neglected here for brevity. Among the photodetector filter models considered were ideal ones such as rectangular and triangular as well as more realistic ones such as exponential and logarithmic [16].

The analytical intractability of the results has prompted us to resort to computer simulations. Currently, efforts are under way to model the statistical characteristics of the system via the Monte-Carlo technique to produce results that support, and supplant, analytic solutions, and thus offer insights into the practical significance of the different noise sources as well as the practical forms of the output signal and noise statistics. We are also hoping to gain some practical insight from the results of the experimental phase of the investigation, (see Section 3) which, combined with the simulation results, should enable us to apply promising detection and estimation techniques and assess the practical magnitude of the achievable accuracy enhancement [17].

Ultimately, we aim to apply this general strategy of analysis and modeling to alternate systems and architectures.

3. Device Characterization for Analog Optical Computing

This phase of the project is concerned with characterizing the performance of common devices, particularly spatial light modulators (SLMs), which are used in analog optical computing systems. The performance issues of interest are those which impact the accuracy of the device in representing quantized numeric states. To this end, the temporal characteristics have been of primary interest. Spatial attributes such as signal uniformity and channel crosstalk will take on greater significance when the temporal characterization is complete.

The device characterization phase has been subdivided into an experimental and an analytical effort. The experimental effort, which to date has engaged the majority of our time, is concerned with developing a low noise test facility, instrumentation, and data acquisition and analysis tools. The analytical effort, which is currently being given more attention, is concerned with developing physical and empirical models of the SLMs so that device behavior can be understood and meaningful experiments can be designed.

The overall goal of the device characterization is to develop a complex field description, through physical models and experiment, to describe the accuracy performance of common SLMs used for the representation of quantized numeric information. These physical models and experiments can then be used to create a statistical description of the systems

performances. These statistical results will then be readily usable in Sections 1 and 2 of this project. Although the SLM is the device of primary interest for modeling, analysis will be performed on sources and detectors as well.

We shall discuss progress on each of the experimental and analytical efforts in turn.

3.1 Experimental Aspect of Device Characterization

The goal of the experimental effort is to gather high quality data (intensity and phase) on the temporal and spatial device characteristics which impact the accuracy of represented quantized numeric data for devices commonly used in optical computing. Temporal stability of a given signal state and the response times between signal levels are of current experimental interest. Although the basic performance attributes of a device or family of devices are of most interest, signal artifacts resulting from the drive electronics packaged with the devices must also be characterized. In general the devices of experimental interest include:

Modulators
Liquid crystal (LC) (both nematic and ferroelectric)
Acousto -optic (AO)
Magneto-optic (MO)
Sources
Helium-Neon (HeNe)
Argon Ion (Ar+)
Light emitting diodes (LEDs)
Laser diodes
Detectors
PIN photo diodes
Avalanche photo diodes

Table I. General device classes of experimental interest.

3.1.1 Facilities

To realize the experimental goals, a low noise test facility along with the associated instrumentation and data acquisition/analysis tools has been built. The facility consists of a 20'x10' Faraday screen room (Figure 8) which provides a low radio frequency interference (RFI) environment within which sensitive measurements can be made. Over the past year shield integrity has been improved.

Additionally, component shielding of power supplies and detector/amplifier circuits within the screen room has been undertaken to minimize the noise resulting from such internal RFI noise sources as laser power supplies.

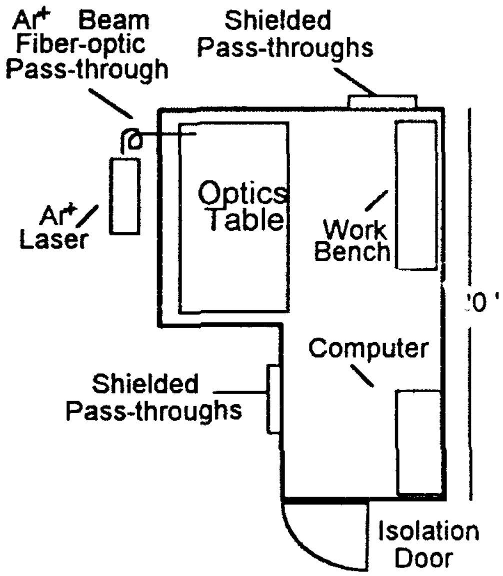

Figure 8. The RFI screen room facility.

Along with quieting the RFI environment, we have also fabricated a second generation of low noise photo-detector circuits. These detector circuits include a prototype of an electronic noise canceller that has the potential to reach the shot noise limit[18]. The design and fabrication of these detector circuits has been motivated by the severity of laser noise revealed by our early experiments. We will discuss some of the measurement techniques and rationale for these detector circuits in the section on experimental methods and initial results.

3.1.2 Data Acquisition and Analysis Tools

Within the screen room facility we have a 33Mhz, 386-based PC with 8Mbs of RAM. For data acquisition this machine contains an Analogic Fast 14-4, 1Mhz ADC with 4Mb of capture memory. Over the past year we have developed the Optical Analysis Simulation Interactive System (OASIS), which is a Microsoft (MS) Windows 3.1 application. OASIS has been built to be the main data acquisition, analysis,

General Features of OASIS
Support for 20 channels of 10,240 samples per channel.(the samples per channel are limited by the number of active channels and the amount of available RAM on the host system)
File support for reading data files.(support for saving files will be added shortly)
Statistical Analysis
Compilation of histograms with bin resolutions from 512 to 10240 over dynamic range of data for all channels. Compilation of several moments.
Hypothesis testing between channels and with synthetic distributions based on the Chi Squares and Kolmogorov-Smirnov tests.
Auto and Cross Correlation and Power Spectral Density analysis between channels.
Frequency Domain Analysis
Forward transforms with several time domain windowing functions.
A wide range of frequency domain filters (magnitude and phase) which can be constructed from primitive windowing functions. A few simple deconvolution techniques
Time Domain Operations
A Synthetic Data Generator (SDG) from which complicated signals can be created from primitive functions, including several noise models.
Time domain modeling via least squares and cubic spline fits to the channel data.

Table II. Functionality of the OASIS software system.

filtering and modeling tool for our experiments. The current functionalities of OASIS are listed in Table II.

The OASIS system is graphically interactive and has been built completely in-house using the MS C7.0 compiler. This in-house development allows OASIS to be augmented in any manner as the experiments and analysis progress. Examples of the time domain data window, histogram window, correlation - power spectral density window, and frequency domain window are provided in Figures 9 through 12.

At this time the data acquisition is performed by a DOS application (also built in-house) and saved to a data file. The short term necessity for this external program has been the difficulty in writing an MS Windows device driver for the Analogic hardware. With the introduction of the MS Windows NT operating system in early 1993 this task will become tractable and the acquisition function will be written into OASIS.

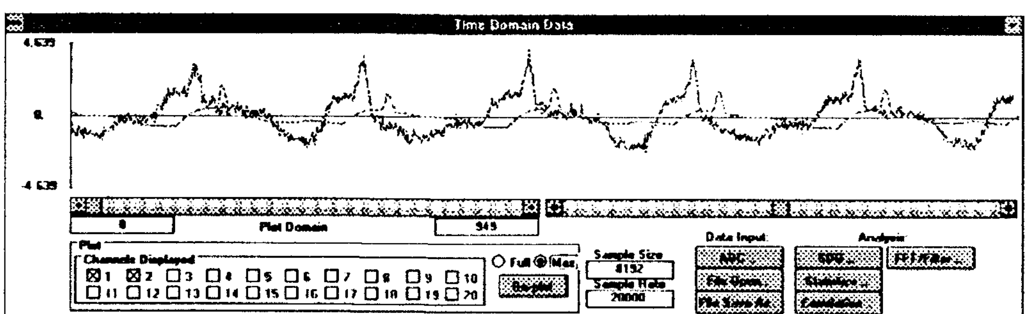

Figure 9.
The OASIS main data window showing 1000 points of the 8192 points for two active data channels. This data is of a noisy DC power supply(the smoother trace) driving an LED and the detected output of the LED(the noisier trace). For this case the power supply ripple

is the dominant signal. Notice: the phase difference between the DC signal and the LED output is due to unsynchronized data captures and is not a real attribute of the LED.

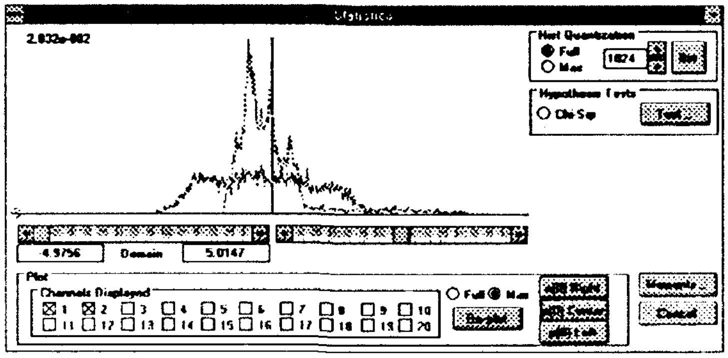

Figure 10. The OASIS statistics window showing a 1024 bin histogram of the two data channels.

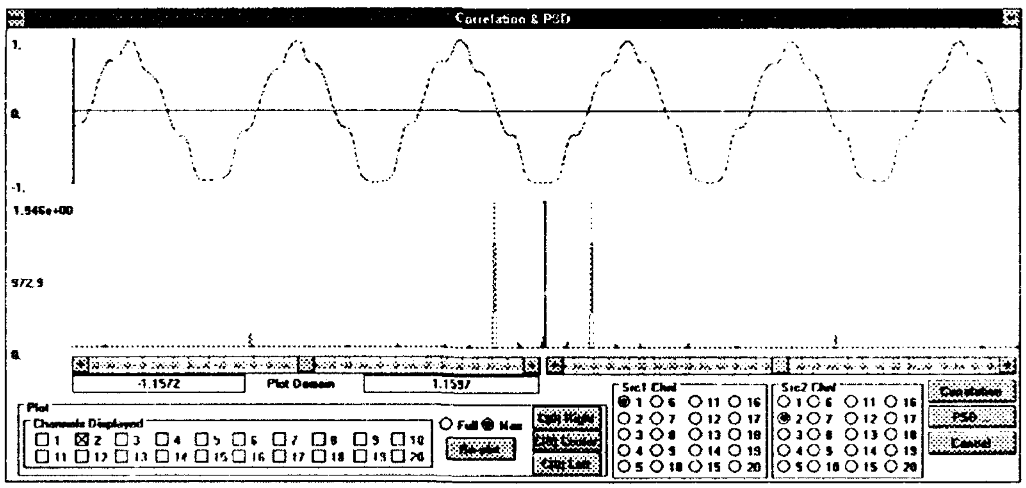

Figure 11. The OASIS correlation and PSD window showing the cross correlation (CCF) of the DC power supply and the LED output (top) and the cross spectral density (bottom). Since the data consists of 8192 points the CCF and PSD are also 8192 points. The displayed plot windows have been centered with the zero of the CCF and DC component of the PSD in the center. The fundamental frequency is at 120Hz.

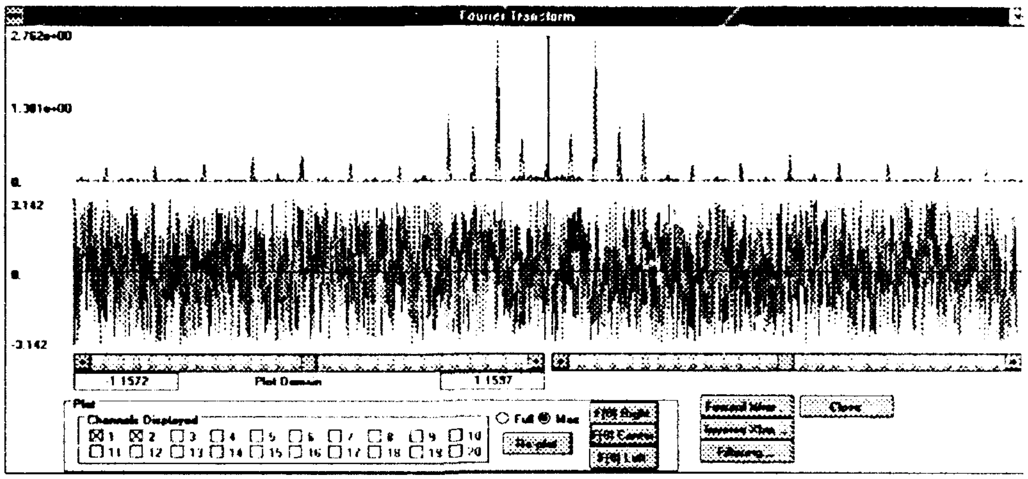

Figure 12. The OASIS frequency domain window showing magnitude of the transform for the DC power supply and the LED output (top) and the phase (bottom). Since the data consists of 8192 points the transforms are also 8192 points. The displayed plot windows have been centered with the DC component in the center. The fundamental frequency is at 120Hz

3.1.3 Experimental Methods and Current Results

To date the majority of experiments have been conducted to isolate problems in the facilities, tools, and equipment. A primary concern borne out by these experiments has been the significant level of noise identified on both the HeNe and Ar+ lasers. This noise results from many deterministic and random factors ranging from power supply ripple and acoustic vibrations to longitudinal mode and transverse mode hopping. We have systematically proceeded to isolate and reduce these effects by several methods, but have not as yet been

completely successful in the exclusion of this noise. Although these attempts to quiet the sources is continuing it is unlikely that this noise will be eliminated as an experimental concern. In conjunction with these efforts we have also pursued methods of post-process removal of this source noise from the experimental results. One method currently used relies on concurrent sampling of two detectors, one detecting the unperturbed laser beam and the other the output of the SLM and, using the correlation and frequency domain techniques of the OASIS system, post-process to remove the laser effects[19]. To date this has been qualitatively sufficient. New post-processing techniques are currently under development. Another approach to removing the laser noise has been to use an electronic noise canceller which simultaneously detects the source and SLM beams and performs an electronic analog subtraction[18]. This module has been fabricated and is currently under test and refinement.

In addition to noise on the laser sources, significant ripple has been identified on the power supplies driving the detector and LED circuits (as seen in the Figures 9-12). Several methods have been satisfactorily employed to reduce this noise to acceptable levels. The data depicted in the figures represents the state of the system before these techniques were implemented.

As the experimental facility has evolved we have been actively testing two commercially available SLMs: the Hughes 4050 Liquid Crystal Light Valve (LCLV), and the Casio TV-1400 Liquid Crystal Television (LCTV). Early results show a significant level of temporal fluctuation on both devices[19]. These fluctuations are predominantly due to their drive electronics.

To fully realize the limitations of an LC-based device for the application of representing quantized numeric information we must have access to the LC cell without the limitations of the drive electronics. To realize this we are currently planning to acquire test LC cells which have no prepackaged drive electronics. These cells will be fabricated using standard orientations of the LC material found in commercial devices (i.e. 45, 90, and 270 degree twists). With these cells we will then be in a position to supply a drive signal of our choosing and to control and meter all aspects of the device. In this way we can develop quantifiable bounds on the performance of the LC cell without being limited by non-optimal drive electronics. These closer-to-ideal devices will play prominent roles in the analytical phase of this project since all device and material characteristics will be known. With appropriate models and performance bounds established we can then go to the commercial devices, with their unknown parameters and

non-optimal drive electronics, and perform meaningful experiments and analysis.

3.2 Analytical Aspects of Device Characterization

Although the bulk of our effort has been focused on getting the experimental tools in place we have recently turned more effort toward the analytical aspects. Here, the basic understanding of the physics of the device under test is fundamental to the design of the experiments.

Our first step has been to define "noise" and "accuracy" from the device perspective. The crux of the problem lies in the fact that we want to represent quantized numeric information on basically linear devices. Understanding the behavior of the device at specific signal levels now becomes the mechanism for determining the achievable dynamic range and bit-resolution. Knowing the physics of the device not only allows one to understand it's behavior but it also provides insight into what can be changed to increase it's performance. One of the analytical goals of this project is to provide this analysis and to produce means by which different device construction and/or operation can achieve better accuracy performance.

The analytical phase will develop along two complimentary paths. The first is an investigation into the device physics. To this date the focus has been on nematic

liquid crystals (NLCs) (both twisted and non-twisted), and ferroelectric liquid crystals (FLCs). It is envisioned that a dynamical model for the LC materials related to accuracy will be developed. This model will be used to guide experiments and to predict conditions in which the LC-based SLM will perform better. The second avenue is along a purely empirical investigation. The goals of this will be to 1) establish the predominant dynamical features of the SLM without being rigorously exact, and 2) utilizing system identification techniques, develop the best communications system model for the "black box" SLM. Both of these results will directly augment the device physics models and drive the experimental investigation.

Other classes of devices such as AO and MO modulators will be investigated in a similar manner as the project progresses.

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[16] M.C. Teich and B.E.A. Saleh, ''Noise in optical sources and amplifiers,'' OSA Tech. Digest Series, Vol. 23, p. 48 (1992).

[17] D.A. Timucin, J.F. Walkup, and T.F. Krile, ''Accuracy in analog optical processors: modeling and enhancement,'' (to be submitted to J. Opt. Soc. Am. A).

RESEARCH PERSONNEL (1992-1993)

1. Faculty:

   Dr. J.F. Walkup, Co-Principal Investigator, Horn Professor
   Dr. T.F. Krile, Co-Principal Investigator, Professor

2. Graduate Students

   S.A. Ellett
   D.A. Timucin
   M.V. Morelli

3. Undergraduate Labratory Assistants

   W. Lu
   D. Hammons

4. Secretary

   E. Gonzales

RECORD OF JOURNAL PUBLICATIONS 1992-1993

Journal Papers Published

1. S.A. Ellett, J.F. Walkup, and T.F. Krile, "Error Correction Coding for Accuracy Enhancement in Optical Matrix-Vector Multipliers," Applied Optics, Vol. 31, pp 5642-5653, September 10, 1992.

2. A.V. Huynh, J.F. Walkup, and T.F. Krile, "A Barium Titanate-Based Optical Quadratic Neural Network Implementing the Perceptron Algorithm," Optical Engineering, Vol. 31, pp 979-985, May, 1992.

Journal Papers in Review

1. D.A. Timucin, J.F. Walkup and T.F. Krile, "Accuracy in Analog Optical Processors: Statistical Analysis," submitted to Applied Optics, in revision process.

Journal Papers in Preparation

1. D.A. Timucin, J.F. Walkup, and T.F. Krile, "Accuracy in Analog Optical Processors-II: Enhancement" (in preparation for submission to J.Opt. Soc. Am.A)

RECORD OF BOOK CHAPTERS 1992-1993

1. S.G. Batsell, J.F. Walkup and T.F. Krile, "Noise Issues in the Design of Optical Linear Algebra Processors," Chapter to appear in Design Issues in Optical Processing, John N. Lee, editor, Cambridge University Press, 1993.

INTERACTION ACTIVITIES 1992-1993

Papers Presented at Major Professional Meetings

1. S. A. Ellett, T. F. Krile and J. F. Walkup, "Accuracy Enhancement of Optical Vector-Matrix Processors" Optical Society of America Annual Meeting, Albuquerque, NM, September 1992.

2. D.A. Timucin, J.F. Walkup and T.F. Krile, "A Decision-Theoretic Approach to Accuracy Enhancement in Optical Linear Algebra Processors," Optical Society of America Annual Meeting, Albuquerque, NM, September 1992.

3. M. Morelli, J.F. Walkup and T.F. Krile, "Noise Characterization of Analog Devices for Optical Computing", LEOS, Boston, MA., November 1992.

Papers Submitted to Major Professional Meetings

1. S. A. Ellett, J. F. Walkup and T. F. Krile, "Reduction of Error Effects in Digital Partitioning by Error-correcting Coding," submitted to SPIE Annual Meeting, San Diego, 1993.

2. D.A. Timucin, J.F. Walkup and T.F. Krile, "Statistical Analysis and Modeling of Analog Optical Processors", submitted to SPIE Annual Meeting, San Diego, 1993.

Other Journal Papers Published

1. A.V. Huynh, J.F. Walkup and T.F. Krile, "BaTi03 based Optical Quadratic Neural Network Implementing the Perceptron Algorithm," Optical Engineering, 31, 979-985, May, 1992.

2. P.C. Chung and T.F. Krile, "Characteristics of Hebbian-Type Associative Memories Having Faulty Interconnections", IEEE Trans. on Neural Networks, 3,969-980, November, 1992.

3. M.E. Hoq and T.F. Krile, "Optical Logic Function Implementation Using a One-Dimension Mirror Device",Optical Engineering, 31, 2413-2421, November, 1992.

Other Interaction Activites

1. Service as Associate Editor, IEEE Trans. On Neural Networks, (Dr. T.F. Krile).

2. Service as Topical Editor for Optical Processing and Image Science, Journal of the Optical Society of America A, (Dr. J.F. Walkup).

3. Presented research briefing to Dr. Alan Craig of AFOSR at Texas Tech University, June, 1992 (Drs. J.F. Walkup, T.F. Krile, plus Dr. D. Mehrl and graduate students S. Ellett, D. Timucin, M. Morelli).

4. Presented talks on "Optical Systems Research at Texas Tech University" at NASA Ames Research Center and at Information Systems Laboratory, Stanford University, Fall 1992 (Dr. J.F. Walkup).

5. National Research Council Senior Research Associateship and Texas Tech University Faculty Development Leave at NASA Ames Research Center and Stanford University (Dr. J.F. Walkup) Research topics relate to noise limitations in optical signal processing and include (1) effects of signal-dependent noise in design of optimal matched filters for optical correlators; (2) applications of error correction codes to optical matrix-vector multipliers for shuttle plume analysis and (3) crosstalk limitations associated with holographic data storage in photorefractive materials assuming phase-coded reference beams.

6. Service on Technical Program Committee for the International Conference on Optical Information Processing, St.Petersburg, Russia, 2-7 August, 1993 (Dr. J.F. Walkup).

7. Service on selection committee for 1992 Newport Research Award (Dr. J.F. Walkup).

8. Lectured on optics and communications topics for Texas Tech's Master of Engineering program courses, Summer, 1992 (J.F. Walkup, T.F. Krile, D.J. Mehrl).

SIGNIFICANT ACCOMPLISHMENTS

1. Development and simulation of a system model incorporating device dynamic range for better quantitative assessment of error-correction code performance.

2. Extension of earlier statistical models to include crosstalk, background, avalanche gain, flicker and generation-recombination noise effects.

3. Analytical and/or numerical evaluations of the output signal statistics for a number of practically interesting device combinations.

4. Construction of the Optical Analysis Simulation Interactive System (OASIS) software for the acquisition, analysis and manipulation of experimental data.

5. Identification of major noise sources of experimental concern using OASIS.